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16. Abstract

The past year brought few achievements in the conquest of outer space. Soviet automatic stations carried out a wide range of investigations of Mars and Venus. "Luna-20" brought soil from the continental region of the moon back to Earth. The "Prognoz" satellites are on 24-hour watch along the earth. A number of important agreements were reached between the USSR and the USA in the area of the investigation of space.

This collection, basically compiled from materials published in the cnetral printing office, discusses these achievements, the commentaries of well-known Soviet scientists acquaint the reader with a wide range of problems.

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SOVIET AUTOMATIC STATIONS INVESTIGATE MARS

The Soviet automatic interplanetary station "Mars-2" and "Mars-3" having become artificial satellites of Mars, at the end of 1971 completed a program of scientific investigation. The instruments on these station performed a variety of observations which revealed much new about the "red" planet. Complete processing and analysis of the data obtained will still take considerable time but the first results can now be given. The American Mars satellite "Mariner-9" made measurements at the same time as our stations. /3*

The insertion into Mars orbit of Soviet and American spacecraft, equipped with mutually complementary complexes of scientific instruments, their simultaneous extended operations and the exchange of information between Soviet and American scientists while in the process of conducting the experiment were favorable conditions for significant progress in the study of Mars.

The orbital vehicles of the stations "Mars-2" and "Mars-3" were inserted into significantly different orbit around Mars, which results from the problems of investigating both the planet itself and the characteristics of the space surrounding it. Both stations approached Mars at a minimum distance of around 1500 km, the maximum distance of the station "Mars-2" from the planet was 25,000 km, and from the station "Mars-3" more than 200,000 km.

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*Numbers in righthand margin indicate pagination of foreign text.

Upon reaching Mars a capsule was ejected from the station "Mars-2", which sent a plaque with a depiction of the coat of arms of the Soviet Union to the planet.

The descent module of the station "Mars-3" landed between the regions Electris and Phaetontis. The television signals of its panoramic cameras was received at the calculated time simultaneously along independent channels so that the signal level was high, and noiseless, however the transmission of signals quickly ceased. On the small portion of a panorama transmitted during this time the markedly contrasting details are not observed. The causes of the sudden cessation of transmissions have not been unambiguously determined. Most probably this was connected with the local features of the landing area, which are completely unknown, or with an intense dust storm occurring on the planet at that period of time.

The possibility cannot be excluded that a dust storm covered the surface details with a "shroud" when the section of the panorma was taken. The study of the results of this complex experiment is continuing. The successful performance of a soft landing on the surface of Mars opens broad perspectives for investigating this planet by direct methods in the near future.

Eleven scientific experiments were performed on board the /4
Soviet artifical satellites of Mars. Seven of these are connected with the study of the planet itself, three were measurements of the parameters of the interplanetary medium and one, carried out in collaboration with French scientists, was an investigation of solar radio emission.

Along the route of flight to Mars the fluxes and energy characteristics of the solar plasma, and also the parameters of the interplanetary magnetic field were regularly measured on the stations "Mars-2" and "Mars-3." The electron concentration in the interplanetary medium was determined according to the nature of radiowave propagation on two coherent frequencies. The three-dimensional structure, directivity, and mechanism of the process of solar emission were investigated on the automatic station "Mars-3" and by conducting the joint Soviet-French "stereo" experiment.

Measurements of the ion component of the plasma along the flight path showed that disturbances of the interplanetary plasma, rising from its interaction with the earth's magnetic field, are observed in the anti-solar direction at distances up to 20,000,000 kilometers. From the zone of disturbed plasma, deflected by the flux of the "solar wind", both components of the plasma, electrons and ions, experience almost periodic fluctuations in velocity. Approaching Mars, when the distance from the sun had significantly increased there was observed a simultaneous decrease of the value of the electron concentration in the interplanetary medium. The electron temperature near Mars proved to be several times less than that of Earth. Numerous measurements with the aid of magnetometers showed that the magnitude of the interplanetary magnetic field was on the average within the range of 5-6 gammas (one gamma equals 10^{-5} Oersted; the intensity of terrestrial magnetism is around 0.4 Oersted).

Most important, to be sure, is the information on the planet itself, for it is precisely for this reason that the stations were sent to Mars. This includes measurements of the surface and soil temperature of Mars, and investigations of its topography and the composition and structure of the atmosphere.

For the first time scientists were able to observe Mars at a close distance for an extensive period of time.

Sections of the surface 6 to 50 kilometers in width were within the field of vision of the instruments on board the automatic stations. Analogous observations with the use of optical telescopes from Earth can only resolve sections of 500-1,000 kilometers, and terrestrial radio telescopes received emissions from the entire disc at once. Therefore it is understandable why artifical satellites of Mars make it possible to investigate the planet in greater detail than can be done from Earth.

Almost all the instruments on the stations are oriented so that upon passing the pericenter (the minimum distance from the surface) they "look" at the planet. At this time the satellite /5
is moving at a speed of 4 km/sec, and the martian surface was examined by instruments from edge to edge for approximately half an hour.

The infrared radiometry, which received the emission of the planet in the 8-40 micron wave length region, measured the surface temperature along the flight path. This is a kind of remote thermometer. The flight paths began in the southern hemisphere, where it was approaching the end of the martian summer during the period of investigation, then intersected the equator and ended in the northern hemisphere. The initial points of the flight plan were located in the region, where it was still morning, and the terminal points, in the afternoon, evening, and sometimes even night hours. The temperature along the flight paths therefore varied within wide limits falling from

+13°C (for 14 hours of the local sun time of the eleventh degree of southern latitude) to -93°C (local time 19 hours, 19th degree of northern latitude). In the region of the northern polar cap the temperature fell still lower, to -110 C.

To know the temperature on the martian surface at different latitudes and at different times is interesting, in the first place, because this is one of the primary climatic characteristics, and in the second place, it is possible to determine the properties of the material of which the soil consists by means of the temperature changes during the course of a day and from place to place.

The low night time temperatures signify that the martian surface cooled off very rapidly after sunset, and consequently, the thermal conductivity of the soil is low. Quantitative evaluations indicate that it corresponds to dry sand or dry dust in a rarified atmosphere. The martian "seas" (dark regions) on the average prove to be warmer than the "continents" (light regions). The temperature difference, reaching 10°, is explained by the fact that the reflectivity of the "seas" is lower, they absorb more solar energy and are more intensively heated. In individual cases the darker "sea" regions cool off more slowly after sunset and, consequently, the thermal conductivity is the soil is greater.

In February the measuring runs of "Mars-3" termiated in the region of the northern polar cap. The infrared radiometer here indicated a temperature below -110°.

In contrast to the southern polar cap, which disappears in summer, the northern cap exists year-round, and it is possible, that the total amount of solid carbon-dioxide and frozen water in it significantly exceeds the amount of these substances in the gas atmosphere of Mars.

The onboard radio telescope measured the intensity and polarization of radio emission at a wavelength of 3.5 cm along the same path. In contrast to the infrared radiometer, which measured the surface temperature, it gave the soil temperature a depth of 30-50 cm. The temperature under the surface at the indicated depth experiences no daily fluctuations, which also testifies to the great thermal inertia and low thermal conductivity of the soil.

In addition to temperature, the dialectric constant of /6
the soil, a value which depends primarily on the density of the soil was also determined. The measurements showed that the variations in the soil temperature and the dialectric constant are connected, that is, that higher values of the dialectric constant correspond to higher values of the temperature in individual areas. This indicates that the density of the soil varies along the course of the measurements. Apparently when the values of the dialectirc constant are great, the material of the soil occurs in a granulated condition.

The infrared photometer in the absorption band of carbon-dioxide gas with a wavelength of 2.06 microns indicated how great the carbon-dioxide gas content was in the martian atmosphere at different points along the path. It determined the pressure at the surface, which in different regions proved to be different due to the different altitude above the mean surface level.

At the mean level the pressure on Mars is equal to 5.5-6 milibars (about 4-4.5 mm Hg.), which was approximately 200 times less than on Earth. Knowing how the pressure varies along the path, it is possible to determine the relative altitudes and to find the surface topography.

In observations from Earth drops in altitude of up to 12-14 km in sections of great extent are observed in the equatorial region of Mars. To study the relief in greater detail is possible only from a satellite.

Thus we have, for example, the path drawn by both Mars-3 on 16 February. At first it passes above the Hellespontus region, the altitude of which is 2-3 km above the mean level. Then it reaches the northeast edge of the light Hellas region, and here the relief drops rapidly (to 1 km below the mean level). Then there is a rapid rise toward the back regions of Iapygia and Syrtis Major, where the highest point is an altitude of only around 3 km above the mean level. In a number of regions drops in altitude are greater. When our stations were inserted into orbit, a dust storm was raging over Mars. For two months the entire planet was covered with dense dust clouds, raised from the surface. Measurements made by the infrared photometer in December, indicated that the height of these clouds was around 10 km above the mean surface level. Above the higher regions these clouds are thinner and above the lower regions they are thicker.

Dust storm on Mars are (several words illegible) /7
phenomenon. The usually transparent martian atmosphere suddenly, in the course of several days, becomes almost as opaque for visible radiation as the cloudy atmosphere of Venus. However, transparency increases, as the photometer measurements indicated,

in proportion to the increase in the wavelength. This indicates a significant proportion of very small dust particles of around 1 micron in the clouds. Such particles ought to settle very slowly, which agrees with the general duration of a dust storm. On the other hand, photographs from "Mariner-9" indicate a rapid increase in transparency toward the end of December. It was incomplete, but after 10 days the visibility significantly improved. In order to explain this it is necessary to assume the presence of a certain amount of rapidly settling particles of the comparatively large 10 micron size in the clouds. Clouds, visible in blue light (wavelength 0.36 μ) and invisible in red light (0.7 μ) were observed several times with the aid of the photometer. Such clouds must consist of particles of less than a micron in diameter.

In general, during the period of the storm the martian clouds, evidently, contain particles of different sizes, whereby their ratio varied in time. Such clouds ought to cool the surface and increase the temperature of the atmosphere, which was, in fact, observed. A kind of "anti-greenhouse effect" was created, opposite the situation on Venus, where the atmosphere is heated as a result of the infrared opacity of the atmosphere.

A photometer adjusted to the absorption band of water vapor with a wavelength of 1.4 μ, showed that the water vapor content during the entire period of investigations did not exceed 5 microns of precipitated water, thousands of times less than in the Earth's atmosphere. Mars proved to be a much dryer planet than was expected: earlier terrestrial observers have sometimes managed to observe up to 50 microns of precipitated water on it. It is difficult to say at this time whether the dry period randomly coincided with the dust storm or whether there is some sort of connection between these events.

Two experiments on the stations "Mars-2" and "Mars-3" were intended for observing the upper martian atmosphere. An ultraviolet photometer was used to record the solar radiation scattered by hydrogen and oxygen atoms in the upper martian atmosphere at altitudes from 100 to several tens of thousands of kilometers. In contrast to the optical complex, all instruments of which "look" downwards, onto the planet, the ultraviolet photometer at the pericenter have been directed towards the "horizon", parallel to the surface of Mars. The instrument recorded the emission of atomic oxygen in three closely placed lines with wavelength of 1300 ångströms and the emission of atomic hydrogen with a wavelength of 1216 ångströms(an ångström equals a 100 millionth of a centimeter).

The density of the scattering atoms and their temperature were calculated according to intensity observations in these lines. Near the surface the martian atmosphere basically consists of carbon-dioxide, however at an altitude of around 100 km under the influence of solar ultraviolet radiation it decomposes into a molecule of carbon monoxide and an atom of oxygen. A similar process of decomposition of water vapor leads to the appearance of hydrogen atoms, which are 16 times lighter than oxygen atoms. Therefore, above 300-400 km the atmosphere on Mars basically becomes an atomic hydrogen one. Nonetheless, traces of oxygen are noted at all points in the orbit, up to an altitude of 700-800 km, where its concentration in all equals 100 atoms per cubic centimeter. The density of the lighter hydrogen drops very slowly, decreasing from 10,000 atoms per cubic centimeter around the planet to 100 atoms and even less at a distance of 10,000 kilometers. Measurements at such great distances were performed in the course of special sessions on the station "Mars-3." /8

As far as the temperature of the upper atmosphere is concerned, in the altitude range of from 100 to 200 km it increases, and above that, it remains constant. Approximately the same picture is observed in the upper atmospheres of Earth and Venus. However strange it is, the upper atmosphere of Mars is more like the upper atmosphere of Venus, than that of Earth.

The second experiment in investigating the atmosphere does not require special apparatus and is based on an analysis of the signals from a centimeter wavelength radio transmitter on the stations at the moment the satellites pass behind the martian disc or come out from behind the disc. This experiment is especially important for investigating the martian ionosphere, which is 10 times less dense than the earth's ionosphere. The ionosphere on Mars is "compressed" to the surface: the maximum electron density is located at an altitude of 140 kilometers (with 300 kilometers for the Earth's ionosphere). At altitudes of around 110 kilometers a second maximum is observed, the electron concentration which is approximately 3 times lower. The possibility cannot be excluded that at altitudes of 65-80 kilometers there may be a third relative maximum with an electron concentration of around 10,000 particles per cubic centimeter.

A complex of three instruments, intended for investigating the magnetic field and the charged particles in the neighborhood of Mars was located on board the stations. In principle such investigations may make it possible to draw a conclusion about the internal structure of Mars, and, in the first place, about the presence or absence of a metallic core in this planet.

In 1965 the station "Mariner-4" did not observe a /9
characteristic magnetic field near Mars. However at that time it flew past at a distance of 9100 kilometers from the surface of the planet. The stations "Mars-2" and "Mars-3" flew past

at a distance of around 1500 kilometers.

Measurements of the magnetic field near the planet were conducted up to this distance with the aid of a sensitive ferro-probe magnetometer. Characteristic variations of the magnetic field, exceeding the interplanetary background level by 8 times are observed. Upon approaching Mars the field intensity increased in all three components of the magnetometer. The possibility cannot be excluded that Mars possesses its own weak bipole magnetic field. However, a supplementary analysis of the measurement data is necessary in order to more confidently answer this question which is extremely important for understanding the nature of the planet.

According to measurements made using electron traps on the satellite "Mars-3", a regular increase in the flux of electrons and the electron temperature is observed near the pericenter of the orbit in proportion to the nearness of the satellite to the planet. In addition a section with hot electron gas was also recorded far from the epicenter, at a distance of 180-200,000 kilometers from the planet. It is possible that this interesting phenomena, differing from the usual concepts of the distribution and temperature of electrons in periplanetary space, is connected with the properties of the cosmic medium in the area of Mars. A charged particle spectrometer, recording solar wind ions in an energy range of not more than 10 kilo electron volts, indicated the presence of a thermal ion zone near Mars. The form of the external boundary of this zone and the magnitude of the flux velocity jump in the solar wind make it possible to assume the presence of a shock wave with the interaction of the solar wind with the upper martian atmosphere.

In the complex of experiments conducted on the satellites "Mars-2 and 3," photographing the planet played an auxiliary

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role, primarily functioning to connect the results of measurements in other spectral intervals. In addition to this, photographs, taken on "Mars-3" at great distances, make it possible to more precisely determine the optical compression of the planet (as opposed to the dynamic compression), to plot the contour of the topography according to the image of the rim of the disc and extended sections and to obtain color images of the martian disc by means of synthesizing photographic images, made with different light filters.

The photographs obtained reveal intensive twilight phenomena, in particular atmospheric luminescence approximately 200 kilometers behind the terminator line (the boundary between night and day) and changes in the color of the surface near the terminator. The stratification of the martian atmosphere is shown in several photographs.

Further analysis of the data will make it possible to obtain much valuable information on the nature of Mars.

(Tass) /10

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Akademik A. Vinogradov

THE SOIL OF THE LUNAR MOUNTAINS

If the station "Luna-16" investigated a "sea" region of the moon (the northeastern part of the Sea of Fertility) then "Luna-20" tested the soil from a typically high mountain continental region. Scientists counted on finding surface rocks of a different nature here. Therefore a landing site for "Luna-20" was chosen 120 kilometers directly north of the landing site of "Luna-16." The boundary between the "sea" and continent is situated exactly half-way between these two points.

"Luna-20" landed in the region of the crater "Apollonius C", at a point with the coordinates 3 degrees 32 minutes north latitude and 56 degrees, 33 minutes east longitude, in a mountainous region, separating the Sea of Crises on the north from the Sea of Fertility on the south. Large young craters are absent in the immediate vicinity of the landing site. The terrain is hilly to complex mountainous, with relative peaks of up to one km. Geologically this area belongs to one of the ancient continental regions of the moon, probably formed earlier than the Sea of Fertility.

The sample obtained by "Luna-16" is a consertal, dark, almost black powder. Its constituent particles primarily belong to rocks of the basalt type. The majority of the particles bore clear traces of fusion-they are glassy or glazed on the surface with many spherical fused formations of the type of solidified droplets of a glassy or metallic appearance.

The soil obtained by "Luna-20" on the whole is also a firable consertal material, but of a light gray color, significantly lighter, than the sample from the Sea of Fertility. In comparison with the soil brought back by "Luna-16", it contains significantly fewer fused particles, which in the sample from the Sea of Fertility produced an intense "mirroring effect." As in the case with the Sea of Fertility, the soil from the continental area of the moon possesses a high capacity for electrization. Its bulk weight, as in the case of the sample obtained by "Luna-16" is 1.1-1.2 g/cm^3. It is easily compacted to 1.7-1.8 g/cm^3. Granulometric analysis shows that the average particle diameter is approximately 70-80 microns. There are more large particles of greater than a millimeter in diameter than in the "Luna-16" sample.

The lighter soil color is confirmed by an investigation of the albedo (reflectivity). The albedo is higher than in the sample obtained by "Luna 16" and "Apollos 11 and 12." For finely divided reolath material in the ultraviolet it is equal to 0.145, in the visible region, 0.200, and in the near infrared, 0.260. The maximum reflection occurs at a wavelength of 4 microns and equals 0.370 (in the case of "Luna 16" in the same conditions--0.280). /12

A microscopic study showed a sharp difference in the soil as compared with samples from the Sea of Fertility. This time fragments of crystalline rocks and minerals with well preserved faces and spallation surfaces predominated; The scorified breccias and spheroids, characteristic for the soil obtained by "Luna 16" were practically little observed. The bulk of the particles is comprised of anorthorsite rock, to a significant degree consisting of feldspar (plagioclase). These are further divided into holocrystalline particles, consisting of anorthosites strictly speaking, and rock particles of the same composition, but of an effusive appearance, that is externally similar to terrestrial volcanic rocks. Individual grains of plagioclase, occuring in all granulometric classes of the soil, may belong here. The larger of these, evidently, are fractured macrocrystalline anorthosite. It is very interesting to note, that in rocks of the anorthosite type different sized inclusions of metallic iron are always found. It is extremely important to note the presence of rocks consisting of plagioclays and olivine.

In contrast to the soil, brought back by "Luna 16", rocks of the basalt type are represented in general by infrequent particles of "sea" basalt, analogous to the basalts of the Sea of Fertility and other lunar seas. A limited amount of rock particles of the gabbro and peridotite types are found.

Thus, it proved to be the case that soil from the Sea of Fertility (as also that from other lunar seas) primarily consists of fragments of basalt type rock, and the soil from the high mountain continental region, attained by "Luna 20" primarily consists of anorthosite. The "sea" soil consists of around 1-2% anorthosite, and the continental soil, around 50-60%. Among the iron containing minerals in the thin fraction of soil, obtained by "Luna 20", 36% is olivine, 57% pyroxene, and only around 1% ilmenite, while in the sea sample from "Luna 16" there is up to 10% of this titanium containing mineral, and in the soil from the Sea of Tranquility ("Apollo 11"), more than 25%.

In the particles of lunar soil we found finely divided metallic iron, concentrated in the surface layers. It is found in a still greater quantity in the surface layer of the soil particles collected by "Luna 20." This metallic iron does /13 does not oxidize in air. It was experimentally shown that iron, possessing the same properties, is driven off from basalts heated to a high temperature in a vacuum.

Pieces of metallic iron, connected with silicase, are frequently observed in the soil, obtained by "Luna 20." Sometimes it consists of two polymorphic types, typical for meteorite metallic iron--kamacite and taenite rich in nickel. In addition metallic iron is also present in soil particles with a very high nickel content or entirely without nickel. The problem of the origin of this iron still remains to be solved.

The soil was subjected to a detailed physical-chemical investigation. Its chemical composition significantly differs from that of the "sea" soils, brought back by "Luna 16" and the "Apollos."

What are the initial data on the main components of the matter brought back by "Luna 20?" The following table gives an idea of this.

Component	Crystalline basalt rock "Luna 16"	Crystalline rock of the anorthosite type with olivine "Luna 20"	Soil (regolath) "Luna 16"	Soil (regolath) "Luna 20"
Silicone oxide	42.95	42.4	41.90	44.4
Aluminum oxide	13.88	20.2	15.33	22.9
Iron oxide	20.17	6.4	16.66	7.03
Calcium oxide	10.8	18.6	12.53	15.2
Magnesium oxide	6.05	12.0	8.78	9.70
Titanium oxide	5.5	0.38	3.36	0.56
Sodium oxide	0.23	0.40	0.34	0.55
Potassium oxide	0.16	0.52	0.1	0.10

The first thing that one notices is the high content of aluminum oxide and especially of calcium oxide both in the crystalline rock and in the soil (regolath) of "Luna 20" as the consequence of the high plagioclays (anorthite) content. Samples of regolath with a similar high content of these oxides had not been obtained from the moon up to this time. The continental regolath contains significantly less iron oxide. Titanium oxide is comparatively low in it in comparison with the "sea" soil, only fractions of a percent. Various more alkalai in the soil from "Luna 20" although the difference is small.

A high content of nickel and platinoids is characteristic

of the consertal continental and "sea" soils. This serves as an indication of the entry of meteorite substance into the material. Thus it is possible to consider that micro- /14
meteorites have struck the surface of the moon to the same degree, both its visible and reverse, mountainous side. The low chromium content is somewhat surprising.

The content of more than 70 chemical elements in the soil taken by "Luna 20" has now been determined according to the mass spectra. This makes it possible to more thoroughly understand the processes which led to the formation of anorthosite in the high mountain regions. From the examples presented above it is obvious that there is a significant difference in the nature of the surface rocks from the "sea" provinces and the high mountain regions of the moon. As regards the "sea" regolath it is possible to confirm that it was formed from local crystalline basaltic rocks, the composition of which varies somewhat in different seas. However, the problem of the origin of "sea" regolath has still not been completely solved. As far as the continental soil is concerned, its origin is a complete mystery.

The distributional boundaries of both soils on the moon are quite clearly defined. This can be judged, for example, according to the boundary between the Sea of Fertility and its northern shore, where "Luna 20" took its sample. Strictly speaking, we know but little about the origin of anorthosites. The discovery of these rocks in the high mountain regions of the moon resurrects old geological ideas concerning the primary anorthosite crust of the earth and, consequently, of the moon. Anorthosites, as is well known, are also found on the earth, particularly in the most ancient archaeozorc and proterozoic formations with an absolute geological age of 3-3.5 billion years. All anorthosites, including lunar ones, contain small amounts of the so-called mafic elements: iron, vanadium, manganese and also titanium. A high content of these elements is characteristic, as we have seen, for the "sea" lunar basalts. A large amount of aluminum and calcium is also found in anorthosites.

On the examples of the distribution of anorthosites in the high mountain regions the value of an investigation of the moon and planets for understanding terrestrial processes, primarily in the early period of life of our planet, is especially clearly manifested. Discovery of the method of formation of anorthosites on the moon would promote an understanding of the geological processes on the earth. Preliminarily it may be said that the formation of anorthosites, evidently, takes place in a process of crystallization differentiation of basic gabbrobasaltic magna. The anorothosite is separated out with a very rapid outflow of magna in the conditions of high temperatures and high vacuum characteristic of the moon. It is true that the requires a certain amount of water in the magna. Meanwhile there are indications that the lunar magna had a high temperature and it contained little volatile components, like water, gases and carbon dioxide. On the other hand, it is impossible not to consider that such volatile compounds could easily escape the moon into outer space. In a word, the problem of anorthosite formation will be at the center of attention in the future.

A wide ranging study of samples, brought back by "Luna 20" /15 is continuing. There is no doubt that scientists will discover new facts of exceptional interest for the cosmogony, geology, and geochemistry of the earth and other planets. The flight of "Luna 20" yielded material of exceptional value.

THE EARTH'S MIRROR /16

Professor Yu. Surkov

From ancient times scientists have been interested in what the moon consists of. However it was not possible to determine this by means of astronomical observations. Hypotheses about the lunar substance included practically all types of rock known on earth. The first important information on the lunar substance, its structure and certain of its properties was communicated by "Luna 9" which made a soft landing on the lunar surface in 1966.

The first satellite , the Soviet automatic station "Luna 10", was soon inserted into orbit around the moon. On board this satellite was an instrument for determining the nature of the lunar rock according to the content of natural radioactive elements in it. It first established that the moon contains igneous rocks, the composition of which is close to the basalts widely distributed in the earth's crust. Several years later scientific laboratories began investigations of the lunar rock, brought back to earth by the "Apollos" and "Luna-16." Although acquaintance with samples in terrestrial laboratories did not bring forth any sensational surprises, these investigations set the beginning of a new stage in the study of the moon.

The first samples of lunar rock belong, as is known, to the "sea" regions. The surface layer of lunar material here proved to be a firable fine grained rock of a dark gray color of low density and hardness--the so-called regolath. It is easily shaped and holds a vertical wall, similar to wet sand, although absolutely dry.

Structurally the regolath is a fine grained granulated material, consisting of particles of several varieties. Its basic components are fragments of magnetic rock, having angular shapes and fresh surfaces, and, slidelike particles of indefinite shape with fused faces and glazed pores. Spheroidal formations, representing solidified drops of melted magnetic rock are present to a lesser degree.

The structure composition and properties of this rock change somewhat with depth. The particle diameter increases, the percentage of melted (vitrified) particles decreases, the density and hardness increase, the elementally and isotopic composition change somewhat as do some physical properties. All these changes are caused by the effects of different cosmogenic factors.

The density of the surface layer of this rock in natural occurrence, according to data transmitted by "Luna 13" is around 1 gram per cubic centimeter. However, evidently, /17
this factor increases with depth. The bulk weight of the rock, brought back from the Sea of Fertility by "Luna 16" and measured in laboratory conditions is approximately 1.2 grams per cubic centimeter, but after shaking and tamping, its density is almost doubled and nearly reaches the density of granite.

Scientists agree that the surface layer of the moon was formed as a result of the decomposition of the crustal lunar rock under the influence of a great number of cosmogenic factors--impacts of large and small meteorites, cosmic rays and solar wind, deep vacuum and sharp temperature changes.

Pieces of dense crystalline rock, evidently cast out of nearby craters as a result of volcanic eruptions or the impacts of large meteorites, are also found on the lunar surface.

Their number increases in moving from the sea regions to the continental regions. In the region of the crater Fra Mauro, where "Apollo 14" landed, for example, boulders the size of a bus are found. It is perfectly obvious that this is non-decomposed crustal crystalline rock. Now it is also well studied. In composition, structure and properties this rock differs somewhat in different regions of the lunar surface.

According to their chemical composition lumar rocks prove to be basically similar to the igneous basalt type rocks which are widely distributed in the earth's crust. In addition different basaltic rocks on the earth differ from one another more than the samples taken from the different regions of the lunar surface. A small difference in composition is also observed between the crustal crystalline lunar rock and the regolath covering its surface. Thus, rocks from the Ocean of Storms on the average contain two to three times less titanium than samples from the Sea of Tranquility. Samples from the Sea of Fertility are more similar to the rocks of the Ocean of Storms and less similar to the rocks from the Sea of Tranquility. Nonetheless, territorially, the Sea of Fertility is situated significantly closer to the Sea of Tranquility. However the rocks of all "sea" regions are similar as to the quantity of basic elements.

As for the basic minerals constituting the lunar rock, there are plagioclays, pyroxene, ilmenite, anorthite and others. The most widely distributed mineral of the lunar regolath is anorthite, followed by augite and ilmenite. All this indicates that the lunar rock is of the basaltic type in the broad sense of the word.

Scientists have carefully studied many other properties of the material brought back from the moon, including its reflectivity, luminescence under the influence of charged particles, X-ray and ultraviolet radiation. The magnetic properties of lunar soil were also studied. The results of these investigations showed that the lunar rock, probably, solidified in a significantly stronger magnetic field. Measured on the lunar surface, it is now approximately a tenth of a percent of that observed on earth. The study of lunar samples indicates that the magnetic field of the moon 3.5 billion years ago was around 10% of the contemporary terrestrial field, that is it was approximately 100 times stronger. However the nature of this phenomenon has not yet been explained. /18

Especially important information was obtained of investigations of the isotopic composition of the individual elements. The age of the lunar rock, which proved to be somewhat different in different regions, was determined in relation to certain isotopes of potassium and argone, rubidium and strontium, uranium and lead. The formation of the rock (its crystallization) took place in the Ocean of Storms around 3.3 billion years ago and in the Sea of Tranquility, 3.7 billion years ago. The age of the most ancient rock, discovered on the moon, is 4.6 billion years. Consequently, it may be considered, that the moon was formed no less than 4.6 billion years ago. These data indicate that the moon, after its formation, had several periods of "local" melting, primarily in the "sea" regions. These meltings could have been caused by volcanic activity or impacts of large meteorites. Although the age of the earth, determined according to radio isotopes, is also around 4.6 billion years, no one on our planet has found a sample of rock which was crystallized more than 3.5 billion years ago. This is explained by the fact that an entire geological epoch on the earth was "wiped out" as a result of the erosion caused by wind and water. Thus, a study of the lunar rock gives us information on the "disappeared" billions of years of the earth's history.

It proved to be the case that the upper layer of material of several centimeters in thickness has been laying on the lunar surface for at least 10 million years, and a layer 1-2 meters in thickness not less than 600 million years. Therefore it becomes clear that this surface layer was formed extremely slowly. On Earth the picture is different. Due to the high techtronic activity and atmospheric phenomena the earth's surface changes continuously and quite rapidly.

The rocks on the exposed lunar surface are also subjected to erosion and continuous decomposition. Its speed, as determined by the traces of cosmic particles in the matter, equals approximately one millionth of a millimeter per year. How many millions of years will pass before the spacecraft, sent to the earth's natural satellite, will be converted into lunar dust!

Despite the huge achievements in the study of the moon, /19
the main problems of its origin and evolution are still far from resolved. Up till now primarily rock from the surface of the lunar seas, possessing a smooth and comparatively uniform terrain, has been subjected to investigations. What kind of rocks compose the lunar "continents", which occupy the greatest part of the lunar surface? What occurs at a depth of even several meters below the surface? These and some other questions are not solved.

The study of the lunar "continents" must now be given priority. Knowledge of the nature of the rock of which they are composed will make it possible to answer one of the principle questions: Does the moon have a solid basaltic crust, similar to the Earth, or did it undergo only partial meltings, and did lava emerge onto the surface only in the regions of the "seas?" In the case of a positive answer to the second part of the question we will be forced to conclude that the bulk of the lunar surface must be primary undifferentiated material, in composition close to stone meteorites.

The moon, evidently, as also the earth, in the initial period of its existence was warmed by the heat liberated during the decay of natural radioactive elements. The lunar material was thus differentiated, and the most easily melted fractions emerged onto the surface. Cooling, they were converted into the lunar crust. In the process of the lava cooling, which proceeded rapidly, the differentiation of material also took place. It is possible that at the bottom of lava lakes, therefore, layers of heavy iron-titanium oxides were formed, and at a depth of several kilometers, layers of different minerals of lesser density. Could not this explain the unusual seismic properties of the moon, which, figuratively speaking, rings like a bell upon its being struck by foreign bodies? On the other hand, it is perfectly possible, that this process is connected with another phenomenon discovered on the moon, the so-called mascons, that is regions with an elevated gravitational field, which force artificial satellites of the moon to change their orbit.

The information obtained in recent years, more and more inclines scientists to ideas according to which the moon was born within the solar system, and evidently, developed in the same way as did the planets. However, the small diameter of the moon could not but be reflected both in the processes, determining its internal structure, and in the processes occurring on its surface. As a result the lunar surface proved to be exposed to the continuous influence of different cosmic factors, which formed its external appearance. The fact that the events /20 which took place on the moon in the distant past left their traces on its surface are of important significance for science and practical application. Almost no evidence of remote geological history remains on the earth, since its entire surface is covered with a layer of sedimentary rock. This explains the great attention which contemporary science has paid to the moon, a unique mirror in which are reflected events which occurred on our planet billions of years ago. Recreating them, we could determine what is hidden beneath the surface of the earth and what natural riches mankind may use in the future.

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MACHINES ON THE LUNAR SOIL /21

Doctor of Engineering Sciences A. Silin

Soviet scientists and engineers in developing lunar drilling apparatus have solved many scientific and technical problems. The study of the characteristics of the active interaction of elements of machines and mechanisms with lunar rocks is a complex and unusual problem.

The specifics of such interaction result, first of all, from the characteristics of the surface layer of the lunar soil, the regolath, which was formed in conditions significantly different from terrestrial ones. In the first place this concerns the splattering of lunar material as a result of meteorite explosions with subsequent fallout of fine particles, and also rocks and boulders, onto the surface.

Another specific factors consists in the bombardment of the lunar surface by the flux of protons, forming the "solar wind," with the simultaneous effects of electromagnetic radiation. The super high vacuum and sharp daily temperature fluctuation of the surface layer increased the unusualness of the situation.

The tendency of the lunar soil to adhere (stick) to those parts of equipment which are in direct contact with the soil is of particularly important practical significance. The intensity of the adhesion may vary within wide limits, determined by the simultaneous action of a great number of factors, including those having a rather precise physical mechanism. In principle, adhesion may appear between the bodies of very different physical nature and chemical composition. It is experimentally proven, for example, that in a super high vacuum strong adhesion may occur between metals and rocks.

Adhesive contact between soil and an operating drill may cause great wear and jamming of the drill in the bore hole. Moreover, in a number of cases there may occur more or less intensive sticking of the soil to parts of the machines and mechanisms.

Its intensity is basically determined by the hardness of the cutting particles of the soil, and also by their shape and dimensions. /22

The study of the characteristics of the interaction with the lunar soil was first conducted on different terrestrial rocks analogous to lunar ones. Studies directly on the lunar surface were the next step. Finally the most definitive stage of experiments began, the study of samples of lunar soil in terrestrial laboratories.

Such investigations were conducted on specially created equipment for a complex evaluation of the engineering-physical properties of the lunar soil in a vacuum and inner gases. This equipment makes it possible to conduct investigations with the usual amount of material, and also with small samples of it.

The studies with small volumes of lunar material required a development of a new method of investigations. The essence of it is that parts of the machines interact with a thin layer of particles of finely divided soil, firmly fixed to the face of the metal sample. The effectiveness of this method is confirmed by a series of control experiments, in which rocks were used both in the form of monolithic samples, and in the form of powders, attached to metal plates.

The abrasive properties of the lunar soil and its analogues were determined by the loss in weight of the metal sample, and also according to the degree of clouding of the organic glass plates, which rub against the attached particles of soil. The clouding of the plate surfaces was determined according to the light transmission. The device used for this consists of an illuminator, a neon helium laser and an optical system.

Analysis of the data obtained from such experiments, made it possible to draw a number of conclusions, having great practical significance.

It proved to be the case that the appearance of the lunar soil, studied as to its frictional properties, is close to that of certain terrestrial rocks, for example crushed basalt. This makes it possible to use it as an analogue of lunar soil in order to evaluate the interaction with drilling equipment. The coefficients of friction of lunar soil against structural materials is quite great. Thus, there is adequate cohesion with the soil for movement, even despite the weak lunar gravity. The relatively low hardness of the soil is compensated for by the six-fold decrease in weight and special adaptations which decrease the specific pressure on the surface layer and, moreover, increase the connection of moving elements of the machine with it. At the same time the lunar soil does not manifest elastic /23
properties in the case of sharp blows, but settles, like loose snow.

The abrasiveness of lunar soil and its micro hardness are significantly lower than the analogous coefficients of terrestrial coarse sand. Evidently, there is no particular danger of abrasive wear of instrument parts and other apparatus, interacting extensively with the soil. However, this does not exclude the possiblity of intensive wear, resulting from the formation of strong intermolecular bonds with contact with the soil in the super high vacuum.

The data from these studies also testify to the possiblity of the penetration of soil particles into cracks and open spaces in the moving parts of drilling apparatus, which is capable of disturbing their efficiency. The builders of drilling instruments had to take account of this possibility.

Direct measurements confirm the extremely low thermal conductivity of the lunar soil, which is explained by its high velocity and the practical absence of the gases in the pores. This means that the heat, liberated, for example, during drilling, has simply no nowhere to go. There is no atmosphere on the moon. In sum, the designer must approach the energetics of drilling in a completely different way. In general the problem of removing excess heat is a very acute problem on the moon.

The extremely low electric conductivity of the lunar material in combination with the high vacuum creates another engineering problem: how to avoid a possible buildup of electrostatic charge during extended moving contact with the lunar surface?

The successful operation of the automatic station "Luna 20" in the new continental region led to more precise conclusion about the engineering problems of the lunar soil. We are now convinced that the drilling conditions in the sea and mountain regions of the moon are different. Further analysis of the data obtained concerning the conditions and results of drilling will clarify a number of problems of the interaction of machine parts with lunar rocks.

"VENUS-8." RESULTS OF THE FLIGHT /24

The fiftieth anniversary of the U.S.S.R. was marked by another great achievement of Soviet astronautics. On 22 July the interplanetary automatic station "Venus-8" completed its four month flight and transmitted unique scientific data from the planet Venus.

Placques with the bas-relief of the founder of the Soviet State Vladimir Il'ich Lenin and a depiction of the arms of the Soviet Union were attached to the descent stage of the station "Venus-8."

For the first time in the history of the study of Venus entry into the atmosphere and landing of a descent vehicle by the station "Venus-8" were performed on the side of the planet illuminated by the sun. The parachute descent into the atmosphere of Venus lasted for around an hour. After performing a soft landing the descent vehicle of the station operated for 50 minutes on the surface of Venus, transmitting scientific information to Earth.

The unique data on the properties of the atmosphere, the characteristics of illumination on the planet and the nature of its surface soil, obtained in the descent process and during operation on the surface, have fundamental scientific significance.

The Soviet program of studying the solar system with the aid of automatic vehicles is successfully brought to life. The flight of "Venus-8" is an important contribution to science, a new giant step in understanding nature.

The automatic station "Venus-8" was planned, taking consideration of the available scientific data about the planet Venus and experience acquired in the building and flights of the "Venus" stations.

As in the case of all the preceding stations of this type, the station "Venus-8" consists of an orbital module and a descent vehicle. The total weight of the automatic station "Venus-8" was 1184 kg, and of the descent vehicle, 295 kg.

The descent vehicle of the station "Venus-8" was subjected to significant modification. The theoretical values of the pressure on the body of the descent vehicle and the maximum temperature of the environment were decreased by carefully analyzing the atmospheric parameters transmitted by the station "Venus-7." This made it possible to lighten the construction of the casing of the "Venus-8" descent vehicle. Additional scientific instruments were provided as a result of the economized weight and a number of measures were taken to increase the operating time of the vehicle on the surface of Venus.

The descent vehicle consists of two sections: instrument /25 and parachute. In the parachute section of the descent vehicle, located in the upper part, are located a parachute system, a radio altimeter, the sensors of scientific instruments and the antenna of the on-board radio complex. In the instrument section of the "Venus-8" descent vehicle are loated the radio technical and telemetry systems, the electrical power source, ventilators and other units of the heat control system, automatic equipment and groups of scientific instruments. In order to provide the necessary temperature conditions in the instrument section of the descent vehicle the efficiency of the external heat insulation shield was increased, and heat absorbers, made of materials with a high heat capacity, were installed within the section. All of this provided for a more extended period of operation of the instruments and systems of the descent vehicle.

For communication with Earth the descent vehicle of the "Venus-8" station used a new antenna system, consisting of two antennas: a spiral one, rigidly attached to the upper part of the vehicle, and an extensible one, extended from the section after landing. On the descent leg radio communication is performed by the first antenna, and after landing the on-board transmitter is periodically switched from one antenna to the other according to the commands of a programming-timing device. This providesfor reliable radio communication between the descent vehicle and Earth.

"Venus-8" was provided with scientific instruments, which made it possible for the first time to perform a wide range of investigations of the atmosphere and surface of the planet on the daylight side, and also investigations of the interplanetary medium on the flight path.

The basic aims in selecting the scientific experiments on the descent vehicle of "Venus-8" was to obtain responses to a number of new fundamental questions concerning the physical chemical characteristics of the atmosphere and surface of Venus.

The statations "Venus-4, 5, 6, and 7", which descended onto the night side of the planet, investigated the atmospheric temperature and pressure according to altitude down to the surface in sufficient detail.

The direct measurements of temperature and pressure made on "Venus-8" confirm that no significant differences in these indicators are found on the day and night sides of Venus. At the "Venus-8" landing site the temperature of the atmosphere was 470±8°C, the pressure 90±1.5 kg/cm^2, which are very close to the values obtained as a result of experiments performed on "Venus-7", which landed on the night side of the planet.

The key question in landing "Venus-8" was whether solar light penetrates to the surface of the planet or is completely absorbed by the atmosphere and clouds. In other words, whether Venus is light during the day or is always gloomy. For this it was necessary to measure the illumination in the atmosphere and on the planet surface. For this purpose the descent vehicle was equipped with a special instrument, a photometer. It was designed for measuring illumination in the wide range of light flux values, which might be expected on Venus, and had to be able to operate in the extremely difficult environmental conditions: the hot and dense atmosphere of Venus. Information was obtained on the amounts of illumination on the entire descent leg down to the surface. These unique data make it possible to conclude that a certain portion of solar rays in the visible region of the spectrum penetrates to the surface of the planet and that there are significant differences in illumination between day and night. Preliminary evaluations of the nature of the variation in intensity according to altitude indicate that the atmosphere of Venus significantly attenuates solar light. A quantitative analysis of the results obtained is being performed at the present time, which will make it possible to evaluate a number of the important parameters determining the optical characteristics of the atmosphere of Venus. /26

As is known, the flight of "Venus-4" made it possible for the first time to determine the basic chemical composition of the atmosphere of Venus, which was later more precisely determined by the automatic stations "Venus-5" and "Venus-6." It was established that the atmosphere of the planet consists of 97% carbon dioxide. The nitrogen content does not exceed 2%, the oxygen--less than 0.1%, and water vapor near the cloud layer less than 1%.

In addition, despite the formulation of certain concepts about the composition and structure of the atmosphere, the problem of Venus's cloud layer remains unresolved. The lack of factual material provides the basis for numerous hypotheses, which need experimental verification. In particular, it is hypothesized that the clouds may contain compounds, containing amonia (amonium salts). In this case, at altitudes below 48 kilometers it is possible to suspect the presence of relatively small amounts of free amonia in the atmosphere. Therefore, "Venus-8" contained an instrument for determining amonium.

The first measurement of this in the atmosphere of Venus was performed at an altitude of around 33 kilometers. The results of the experiment provide a basis for considering that in the section measured a small amount of amonia is present in the atmosphere. Its cubic content may be estimated as 0.01-0.1 percent.

The horizontal wind speed was measured during the descent /27
of "Venus-8." At altitudes greater than 45 kilometers it was about 50 m/sec, decreasing to a value of less than 2 m/sec below 10-12 kilometers. These measurements indicate the presence of a zonal (latitudinal) wind, directed from the terminator toward the day side, that is in the direction of proper rotation of the planet, and have important significance for understanding the atmospheric dynamics of Venus.

In the program of investigations of Venus on "Venus-8" great attention was given to the study of the physical-chemical properties of the surface of the planet. Estimates of the dialectric permeability and density of the soil were obtained from an analysis of the level of radio waves reflected by the surface, studied during the descent process. The results of these measurements give a basis for considering that in the region of the descent the surface layer of the planet is quite porous, with a solar density of not much less than 1.5 g/cm^3. "Venus-8" was equipped with a gamma spectrometer, which determined the content of radioactive elements in the Venutian surface layer according to their gamma radiation. After the descent vehicle landed on the surface of the planet an increase in the total density of gamma radiation was recorded, which is connected with the addition of the effect from the decay of the natural radioactive elements contained in the Venutian surface layer. Measurement of the gamma radiation spectra made it possible to make a quantitative determination of the uranium, thorium, and potassium content in the surface layer.

According to preliminary data, the surface material in the region of the landing site contained 4% potassioum, 0.002% uranium and 0.00065% thorium, similar to the composition of terrestrial granite rocks both in the content of radioactive elements and their proportion. Thus, "Venus-8" discovered a rock, relatively rich in potassium, uranium and thorium. In terrestrial conditions such a ratio of elements, first of all relatively rich in potassium, is characteristic for rocks, subjected to secondary alterations under the influence of different environmental factors after their primary melting within the bowels of the planet. These data are an important contribution to the study of the geology of Venus. Although they were obtained for a small section of the planet, further investigations will make it possible to encompass other regions and to draw definite conclusions about the processes taking place in the solid mantle of Venus, and the nature of its evolution.

During the flight of "Venus-8" an anomolous increase in solar activity was observed, which strongly influenced the level of intensity of cosmic rays in different energy bands. Four great solar flares were recorded against a background of increased solar activity, during which the solar intensity of protons with energies of more than one million electron volts and 30 million electron volts also increased sharply. Significant increases in the intensity of galactic cosmic rays, arriving /28
from the more remote regions of space, were also noted. Similar anomolous increases in solar activity were recorded earlier, in particular, by the instruments of "Venus-7, Lunokhod-1" and "Mars-2 and 3."

Measurements of the ultraviolet radiations created by the neutral atomic hydrogen scattered in interplanetary space were conducted on the flight path and upon approaching Venus. In certain areas of interplanetary space the intensity of this radiation increased by two to three times. The intensity of the radiation in the narrow ultraviolet spectral region, created in the basic background of bright blue stars, was also measured.

The successful flight of "Venus-8" confirms the correctness of the engineering decisions made in designing this vehicle, designed for operation in the extremely complex conditions on the surface of Venus.

The scientific results, obtained by "Venus-8", made a valuable contribution to our knowledge about Venus and were an important step on the road of the continuous expansion of ideas about its nature.

This new important achievement in space, made on the fiftieth anniversary of the formation of the U.S.S.R., is a valuable gift of Soviet scientists, engineers, technicians and workers on the occasion of this celebrated date.

(Tass)

EARTH AND VENUS--DISSIMILAR SISTERS /29

Professor V. Moroz

The study of Venus with the aid of descent vehicles is one of the most important areas of Soviet space studies. "Venus-8" is the fifth spacecraft which successfully descended into the atmosphere of this mysterious planet and transmitted new data about it, obtained by means of direct measurements. In the U.S.A. the first experiment of this type is only planned for 1975.

What do we now know about Venus and what would we like to find out in the future? Venus, like Earth, moves along an approximately circular orbit. The mean distance from Venus to the sun is 108 million kilometers; it is 1.4 times closer to it, than the Earth is, and obtains approximately two times more energy from it per unit area. However, Venus reflects solar radiation significantly better than our planet does. The greater part of the radiation, reaching the boundaries of its atmosphere, is returned to space, and as a result approximately the identical amount of solar energy goes into heating both planets.

Moreover, Venus and Earth are almost identical in diameter and mass, and therefore, also in density and acceleration of gravity at the surface. These two planets are real sisters. However it proved to be the case that the sisters are not alike. According to the measurements of "Luna 7," conducted on the surface of Venus, the temperature there reaches 475-500°C.

The atmosphere almost entirely consists of only carbon dioxide gas, and there are huge amounts of it: the pressure at the surface of the planet reaches 90-100 atmospheres. There is also another peculiarity--there is very little water in comparison with Earth. What would become of Earth's oceans if our planet were heated to such a temperature? They would evaporate, the pressure of the water vapor would be around 300 atmospheres, and water vapor would become the mean component of the atmosphere. Venus however, in essence is waterless. The relative water vapor content was evaluated spectroscopically with the use of terrestrial optical telescopes, by radio-astronomical methods and, finally, measured directly in the atmosphere of the planet by the Soviet stations "Venus-4, 5 and 6." Judging by all these data, the relative water vapor content in the atmosphere of Venus does not exceed 1%.

According to contemporary concepts, the planets were formed as a result of the coalescence of solid particles in a cold protoplanetary cloud, surrounding the sun in the epoch of its formation. The earth was able to preserve its primary atmosphere, similar in composition to the sun (hydrogen, helium, inert gases, especially neon), for only a short time. The /30 primary atmosphere was almost completely lost (with the exception of the heavy inert gases) and a secondary atmosphere, consisting of the products of volcanic activity replaced it.

The primary volcanic product was water. Ten times less carbon dioxide was liberated. 300 times less nitrogen was released. Molecular oxygen appeared comparatively late, when plants occupied the earth, this is a specifically terrestrial gas. If there were no life on earth there would be almost no molecular oxygen. The biosphere performed another important act; it removed the greater part of the carbon dioxide from the atmosphere which then entered the composition of sedimentary rocks such as limestone. Nonbiological processes, binding carbon dioxide into rocks (the reactions of the conversion of silicates into carbonates) also proceed in the presence of liquid water, of which there is a more than sufficient amount on the earth.

The similarity of Earth and Venus in diameter and mass indicates a similar inernal structure of both planets. Therefore it should be expected that volcanic processes would take place approximately identically on them. In some regards the similarity actually exists: for example, the amounts of carbon dioxide gas, liberated into the atmosphere of both planets during their evolution is approximately identical. Only, on the earth, it did not remain in the atmosphere but was bound into sedimentary rocks quite rapidly. However in the amount of water vapor thc difference is great.

How could this happen? This is one of the principle enigmas. There exist two basic hypotheses. The first supposes that Venus was formed "waterless" from the beginning due to the fact that in this part of the primary protoplanetary cloud there were no ice particles due to the greater closeness to the sun (and a higher temperature). The second hypothesis /30
maintains that the Venutian atmosphere liberated the same amount of water, as did the earth, but that almost all water molecules were decomposed by the ultraviolet radiation of the sun and converted to hydrogen and oxygen. Then the hydrogen escaped into interplanetary space, and the oxygen reacted with other gases.

The choice between these hypotheses is a matter of the future. One of the possible methods of making this choice consists in determining the relative content of deuterium and hydrogen in Venutian water vapor and some other hydrogen containing gases, which are present in the atmosphere of Venus in small amounts. The investigation of the density of deuterium and hydrogen in the upper atmosphere, which was conducted by "Venus-8" has important significance. Patterns of deuterium are heavier, therefore they escape the atmosphere of a planet less actively than atoms of hydrogen, and if the second hypothesis is correct, deuterium should have accumulated in the atmosphere.

Certainly, given such dry climatic conditions, life can- /31
not exist on Venus. It is very probable, that the absence of water, the great amount of free carbon dioxide in the atmosphere, the high temperature and absence of a biosphere are mutually conditioned phenomena, whereby the lack of water is the main factor determining the rest. Without water a biosphere could not form and processes of binding the carbon dioxide could not proceed effectively. It accumulated, formed an atmospheric coat, increasing the temperature, and the atmosphere gradually acquited its contemporary characteristics. It is not impossible that the same thing would have happened with the earth if it had been dehydrated to the same degree as Venus.

We have discussed only one of the problems of the investigation of Venus disturbing scientists, the problem of the evolution of its atmosphere. This is not the only enigma. The physical mechanism of the heating of the Venutian surface is still not completely understood, although it is clear, that it is connected with the great opacity of its atmosphere in the infrared region of the spectrum. The question of the composition and structure of the cloud layer of the planet and its role in heating the atmosphere is not resolved. However we can be assured that we will obtain the answers to these questions quite soon.

It should be emphasized that the problem of the evolution of planetary atmospheres is not at all an abstract one. Even a small change in the composition of the atmosphere and the climate on earth is very dangerous, and therefore it is very important to understand how the composition of a planetary atmosphere is formed and what evolutional factors determined climate. A detailed study of the other planets in the solar system may provide the key to the solution of this most important problem for all mankind.

TO VENUS FOR THE SAKE OF EARTH /32

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Doctor of Physical-Mathematical Sciences S. Zilitinkevich

The discovery of the planet Plato by means of mathematical calculation is a prime example of scientific foresight. However, the methods and instruments, which the scholar possesses today make it possible to solve even more laborious and complex problems.

Only recently, as a result of the work of radio astronomers and the flights of automatic stations has it been possible to obtain information about the properties of the atmosphere of Venus and the rotation of the planet. However, until the present time we had not had available experimental data on the winds which blow there. Nonetheless, the material which has been accumulated has already made it possible to make a theoretical calculation of the wind system and the temperature distribution, that is the general atmospheric circulation of this planet. Calculations of the "weather" of Venus were made in 1969-1972 in the Oceanology Institute of the Academy of Sciences, U.S.S.R.

We should explain that we are dealing here with a numerical experiment. It was initially believed that the atmosphere of Venus completely lacked winds, that the surface temperature was everywhere the same and that it decreases with altitude according to the so-called adiabatic law (which corresponds to complete intermixing). Then the solar heat source "was included" and changes in the condition of the atmosphere over the course of time were calculated. Thus, the numerical experiment reproduced the theoretical behavior of the atmosphere, as it would have been if the temperature were leveled out and the circulation were made "stationary," we would give it the possibility to again develop. There was every reason to expect that after a more or less extensive period of adaptation the model of the atmosphere would lead to a condition of dynamic equilibrium with the external conditions.

Calculations showed that equilibrium conditions are obtained after approximately one terrestrial month, and as a result of the entire experiment information was obtained about the changes in time of the wind speed and direction, the temperature, atmospheric pressure, vertical gas movements, heat flows, and friction of gas on the surface in the course of the entire Venutian daily cycle--approximately 117 earth days.

The results of the experiment reduce to the following. The atmospheric circulation of Venus is practically symmetrical relative to the equator and developed as a consequence of the temperature differences between the day and night hemispheres. These differences are constantly supported by the fact that /33 the day side of the planet is heated by the sun and the night side is cooled due to natural radiation.

The circulation is not symmetrical either relative to the axis of rotation or relative to the sun-Venus line: the region of greatest heating approaches the evening terminator, and the coldest region is found at the morning terminator (the terminator is the line dividing the day hemisphere from the night one). The temperature differences at different points on the planet were perceived as being very small--one or two degrees in all.

The system of winds is the following: In the lower layers the gases, forming the atmosphere of Venus, flow to the most heated regions, there they rise upwards and, dispersing in the upper layers, are gathered in the "cold" region, where they again drop downwards. These movements encompass the entire planet; Large scale vortices of the type of cyclones and anti-cyclones are absent. The typical wind speed somewhat exceeds 5-6 meters per second. We should remember that on Earth the typical wind speed is close to ten meters per second, but on Venus the atmospheric density is ten times greater, and the usual wind pressures are ten to fifteen times greater than on Earth; they correspond to our hurricane winds.

The frictional source on the surface of Venus is also ten to fifteen times greater than on Earth. Therefore it may be expected that the terrain of the planet is smoothed out. It is curious that, according to calculations, the vertical speeds reach several centimers per second (on Earth they are measured at a few milimeters per second). The entire lower atmosphere of Venus (the tropisphere) is in a state of conductive intermixing: on the day side this is caused by heating from below, and on the night side by cooling from above as a result of natural radiation.

To be sure, all this information requires further improvements. The mathematical model can be and must be perfected by introducing a more detailed description of the vertical structure, and considering new information on the observed properties of the Venutian atmosphere upon which the calculations are made. The new data transmistted to Earth by the automatic station "Venus-8", we hope, will also provide material for a further refinement of the initial parameters of this calculation, and for comparing theoretical results with actual results.

It might be possible to conclude an article on the circulation of the atmosphere of Venus at this point. However, the reader might correctly ask: Why are such investigations necessary, for what reason do we need to know the circulation of another planet and what practical value may be derived from this knowledge? Such questions deserve a detailed explanation. We will restrict ourselves to presenting certain considerations of geophysics, the science studying our planet. One of the most important problems of geophysics is to learn to theoretically predict how "dynamic equilibrium conditions" (a well known term) can be created on our planet as a result of the conscious or involuntary interference caused by human activity.

The practical interest in this problem is manifest. The /34 development of technology proceeds so fast that the question already arises of what is the further destiny of the excess carbon dioxide, entering the atmosphere from the burning of fuel and whether or not the accumulation of carbon dioxide, creating a "greenhouse effect", would lead to a catastrophic warming of the climate? Another example is if the polar ice caps are stable, would not a comparatively small thermal interference lead to their disappearance or, on the contrary, a catastrophic increase in their magnitude?

Many such questions arise. Probably, the only way to give them a well-based scientific answer is by conducting numerical experiments, simulating our atmospheric regime in altered conditions. For this it is necessary to hypothesize a universal physical-mathematical model of atmospheric circulation, which would describe not only the situation now existing on Earth, but all other possible conditions. But what material could verify such a model? Here the planetary atmospheres prove useful. Studying them will enable us to more thoroughly understand the processes taking place on Earth.

THE AUTOMATIC STATIONS "PROGNOZ" KEEP WATCH /35

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Today, the launching of a spacecraft is a routine, universally comprehended step in the conquest of space and the development of space technology, the solution of a great number of problems of an applied scientific nature and an attempt to steal one more secret from nature.

In this sense the orbital insertion of the artificial earth satellite "Prognoz" and "Prognoz-2" is a very important landmark in the history of studying the entire scope of the mechanism of Sun-Earth interconnections.

The value of the information about the structure and evolution of the state of the earth's atmosphere, obtained by means of spacecraft and high altitude geophysical rockets, cannot be questioned. During the last fifteen years a whole series of important geophysical discoveries have been made, which have made it possible in a new way to examine the structure of the gaseous envelope of our planet, the nature of the physical-chemical processes taking place in it, the activity of the sun and the properties of interplanetary space. At the same time we are forced to admit that our knowledge about the earth's atmosphere and the behavior of the sun is far from exhausted.

Let us take the problem of the dimensions of the earth's gaseous envelope. At what height above the surface of the planet does its upper boundary occur? How is this boundary expressed in terms of physical characteristics? These questions are far from idle. The answers to them have great scientific and applied value at the present time. Calculation of the radiation situation and predictions of it in order to provide for the safety of the flights of astronauts, calculation of the radiation balance of the earth-atmosphere system and the radiation balance of the earth for developing reliable methods of long-range weather forecasts, analysis of the processes of the transformation of solar energy in the earth's atmosphere for explaining the basic laws of the sun-earth relationships; these are a number of questions, the answers to which to a great degree depend upon a reliable determination of the position of the upper boundary of the atmosphere.

From the geophysical point of view the atmosphere is the gaseous envelope of the earth, separating the surface of our planet from outer space, unaffected by our planet. Moreover, the state in which the gas must occur has not been completely determined: in the molecular or atomic, in the usual or ionized, and the factors, predominantly influencing the formation of particular layers of this envelope. That is, where such an /36 approach to the given problem both the radiation belts and the hydrogen geocorona may be considered to be constituent parts of the earth's atmosphere.

What, until recently, was decisive in determining the level taken to be the upper boundary of the atmosphere? The altitudes to which measuring instruments could be sent, and the degree of perfection of the measurement equipment used. It is pertinent to remember that after the last two decades the upper boundary of the atmosphere was moved from 2,000 kilometers to 20,000 kilometers, and in recent years this level has been "raised" still higher. In addition different scientists have taken particular features in the behavior of individual characteristics of gas to be the criterion for determining the upper limit of the atmosphere: density, electron concentration, nature of the dissociation and recombination of molecules and atoms and so forth. In each individual case this boundary was determined quite arbitrarily, without sufficiently objective criteria. At the same time space experiments very convincingly indicate that such a boundary actually exists; this is the magnitopause, that is the transition layer formed by the interaction of the solar plasma (solar wind) with the upper magnitosphere at distances of from ten and more earth radii from the surface. Moreover, within the magnitosphere the nature of the processes is basically determined by the state of the earth's magnetic field and the action of the solar wind, while outside the magnitosphere (beyond the magnitopause), only by the state of the interplanetary medium and the activity of the sun. That is, the magnitosphere must also be considered to be part of the earth's atmosphere, irregardless of the fact that the upper boundary of the gaseous envelope of our planet is thus "moved out" to 70,000 kilometers and more from its surface.

Another interesting problem of the physics of the upper atmosphere is the problem of the value of the solar constant. According to the concepts which have been formulated it is considered that the integral value of the flux of solar radiation, arriving per unit area of the upper boundary of the atmoshere is around 1.88 cal/cm^2 per minute. This value is called the "solar constant." It is widely used in meteorology and in other disciplines, using data about the sun-earth interconnections.

However, numerous space studies indicate that the value of the flux of solar radiation, arriving at our planet, experiences a number of significant fluctuations, in the first place caused by variations in the state of solar activity.

Thus, for example, beginning from 12 December 1970 a significant and extensive increase in the intensity of corpuscular fluxes and short-wave radiation, caused by a series of mighty solar flares, which occurred on 10 and 11 December, was recorded.

Toward the end of July and the beginning of August 1972 /37 a series of extremely intense flares was recorded on the sun. The intensity of the geomagnetic effects which followed on the earth after these flares had not been observed for five years.

Naturally, after such manifestations of solar activity the flux of emissions from the sun to the earth did not remain constant. As the data obtained with the use of the spacecraft "Luna 17," "Lunokhod-1," "Venus-7" and others (including the "Prognoz" satellites) indicate, the power of the corpuscular fluxes, which attacked the earth, and more precisely its atmosphere during the period of the above-mentioned disturbances, exceeds the power of the mean solar wind by several thousand times. Moreover, in all probability this is not the limit. Fluctuations in the intensity of the solar flux in the range of ultraviolet, X- and Gamma rays were also observed.

The most powerful flares, occurring in the last two years, have been mentioned above. However, the sun "breathes" continuously, that is its activity continually changes. It is completely natural then that the velocity of the corpuscular fluxes of solar plasma continually changes and the energy relation of the different portions of its spectrum changes, that is the integral power of its emission varies very markedly.

However, we continue to operate with the term "solar constant," while for a long time now it has been necessary to speak of a "solar mean," that is to impart a completely different reading to this concept.

As the analysis shows, for an extended study of the processes taking place in the earth's atmosphere and simultaneously beyond its boundaries, it is necessary to have automatic stations the orbits of which would both pass through the earth's atmosphere and go beyond its limits into open outer space. Such stations were the Soviet automatic observatories "Prognoz" and "Prognoz-2" launched for the purposes of studying the processes of solar activity and their influence on the interplanetary medium and the earth's magnitosphere on respectively 14 April and 29 July 1972. They were equipped with scientific apparatus, intended for studying the corpuscular, gamma and X-ray emission of the sun, the fluxes of solar plasma and their interaction with the earth's magnitosphere, and also for further study of the magnetic fields in space about the earth. The station "Prognoz-2" was also equipped with a French device for conducting experiments studying the characteristics of the solar wind, the external regions of the magnitosphere, solar gamma radiation and scanning for neutrons of solar origin.

The most characteristic feature of this space experiment is /38
the following.

In the first place this is the great ellipiticity of the orbits of the automatic stations "Prognoz" and "Prognoz-2" and the unique spacial orientation of these orbits. As its seen from the diagram, after the orbital insertion of the artificial earth satellites their perigee was 900-950 km, and the apogee, around 200,000 km. The angle of inclination of the orbits was approximately 65%, and the period of their rotation around earth, around 97 hours, i.e. a little more than 4 days.

In order to insert a satellite into the above-mentioned orbit, the insertion process was performed in two stages. In the first stage the spacecraft together with the last stage of the rocket vehicle (the accelerating unit) were inserted into an intermediate orbit. Then, in agreement with the flight program, the last stage of the launch vehicle was automatically ignited, inserting the automatic stations into their working orbits.

This type of inserting satellites into calculated orbits is an exceptionally difficult task.

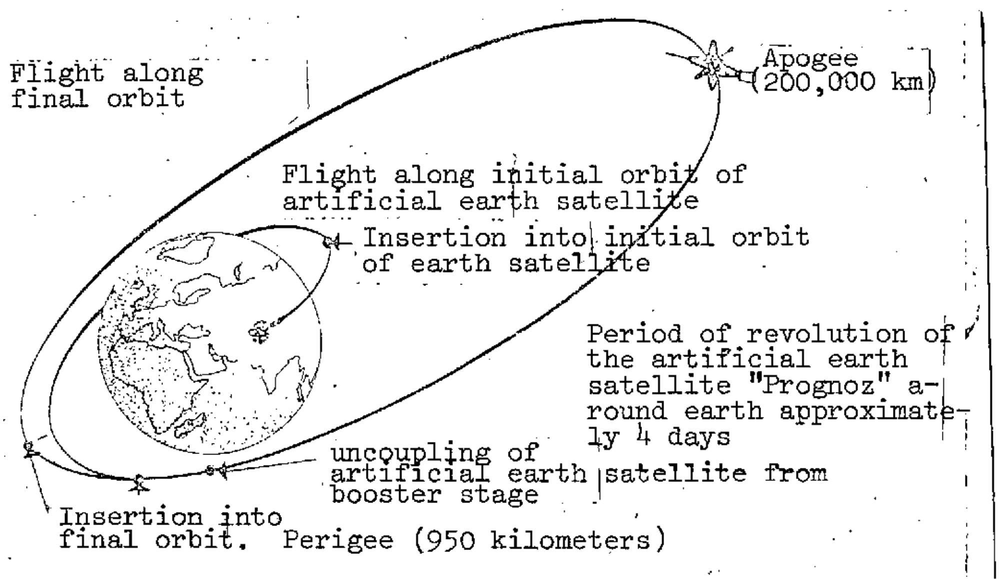

Diagram of the Launch of the Artificial Earth Satellite "Prognoz" into Outer Space

It is necessary here to control the operating time of the launch vehicle at different sections of the insertion process with maximum accuracy, to strictly control the parameters of the launch trajectory both in the intermediate and in the final orbit of the space station, and finally, to strictly control the motion speed at the moment of separation of the satellite from the last stage of the rocket. /39

To a great degree the nature of the experiment also depends on which part of the earth's gaseous envelope the spacecraft is launched into: in the direction of the sun, the gaseous tail, etc. This is undoubtedly a quite important detail of the experiment, since the earth's atmosphere and its magnetic field at great altitudes undergo significant deformation under the influence of the solar wind. Therefore the automatic stations "Prognoz" and "Prognoz-2" were launched in the direction of the sun. At the same time in launching "Prognoz-2" the solution to another more particular problem was envisioned: measuring the parameters of the gas medium and geomagnetic field during the passage of the automatic station on the ascending branch of its first revolution through the region of the northern neutral point of the magnitosphere.

Over the course of time in connection with the rotation of the earth around the sun the orbits of the "Prognoz" satellites leave the direction of the sun, and after five to six months the stations necessarily enter the zone of the gaseous tail of the earth's atmosphere. Thus, with the prolonged flight of an automatic station one device can be used to make an "inspection" of almost all parts of the earth's gaseous envelope. However, in this case many components of the experiment, such as the state of solar activity and geomagnetic activity, can significantly vary over time. Therefore it may prove to be that the results of measurements obtained will not be completely representative. In order for this not to happen it is necessary to have in flight at the same time several stations of the same type (in the given case several "Prognoz" satellites), the orbits of which are appropriately arranged in space. Or, in other words, it is desirable to have a system of several objects of the same type, which could perform a simultaneous investigation of all parts of the earth's atmosphere. There is no doubt as to the value of such investigations.

Unfortunately, highly elliptical orbits with time significantly changed their parameters under the influence of the gravitational fields of the sun and moon. In the given case this causes a change in the altitude of the perigee of the orbit. As observations of the evolution of the orbit of the automatic station "Prognoz" indicate, on the tenth revolution the altitude of its perigee was already 2,000 km, and the apogee, 199,000 km. On the twentieth revolution it had significantly leveled out to 4700 and 197,000 km, and on the fortieth, 7200 and 194,000 km. The same kind of picture of change in the orbital parameters was also observed in the case of the artificial earth satellite "Prognoz-2". On the tenth /40
revolution the altitude of its perigee and apogee was respectively 1,000 and 199,500 km, and on the twentieth revolution, 2,000 and 199,000 km.

Such a "leveling out" of the orbits of automatic stations has to be considered in developing the program for the space studies to be conducted by this type of device.

The bad thing is that from revoution to revolution the "Prognoz" spacecraft moves from the lower layers of the atmosphere to higher ones, and scientists are deprived of simultaneous comparative observations of the state of all layers of the earth's atmosphere, made by one craft. Therefore in order to fill in the existing gap it is necessary to use the results of similar experiments made on "Low flying" satellits of the "Kosmos" series. At the same time the complex use of different spacecraft aids in the development of a method for comparing scientific measurements, made by vehicles flying at different altitudes, and to select the best quality instruments for use in further geophysical investigations.

On the other hand, as a result of the change in the altitude of the perigee the "Prognoz" stations are able to conduct a more detailed investigation of the parameters of the earth's atmosphere at different altitude levels "in steps".

A second feature of this space experiment is that the selection of onboard scientific apparatus used makes it possible to perform a broad program of measurements of environmental parameters both within the earth's atmosphere and outside it.

Naturally, this imposed certain conditions on the structural makeup of this series of satellites.

The automatic station "Prognoz" is an airtight cylindrical container with spherical ends. The weight of the station after its separation from the last stage of the launch vehicle was around 845 kg. Within the container are located the scientific instruments, several systems, providing for the normal operation of the station as a whole and the apparatus of the radio complex and telemetry systems. Outside are located the sensors of the scientific equipment, optical sensors, actuator devices of the satellite orientation system, oxygen tanks, solar battery panels and antennas. The sensors of the scientific equipment are basically located on the upper end of the automatic station, where a special platform is mounted for a more convenient placement of of the sensors.

The entire complex of scientific apparatus, installed on the "Prognoz" automatic stations can be divided into four basic groups in relation to the nature of the phenomena studied. /41

An X-ray spectrometer and a gamma ray spectrometer belong to instruments of the first group, designed for observation of the sun's electromagnetic emission in the short wave portion of its spectrum.

Instruments of the second group measures fluxes of cosmic rays and high energy particles both of solar and gallactic origin. Proton flux, alpha particles and heavy nucleus spectrometers in several energy bands are used for this.

The third group includes instruments, designed for recording the characteristics of the solar plasma on different sections of the flight path and for measuring the transition region between the shock wave front and the boundary of the magnitosphere.

The instruments of the second and third groups perform complex observation of the corpuscular component of the sun's radiation and the transformation of solar corpuscular fluxes within the earth's atmosphere. In addition investigation is made of the charge and energy spectrum of cosmic radiation, the energy spectrum and angular distribution of electrons and protons, which makes it possible to explain a number of significant features of the mechanism of sun-earth interconnections.

And, finally, the fourth group includes all the remaining instruments on board the station. These instruments measure the intentsity of radio emission in different wave bands, trace the variation of magnetic field characteristics and measure the absorbed dosage of ionized emissions. As is seen from the list of onboard equipment, the flight program of the automatic stations is very full.

In order to provide for high quality scientific measurements the body of the "Prognoz" station was stabilized in space so that the longitudinal axis of the satellite is constantly oriented toward the sun. This is performed by a solar orientation system, consisting of a system of optical sensors and gas jets. The solar orientation system directs the longitudinal axis of the satellite in the direction of the sun with a subsequent twisting of it around its axis. Such a gyroscopic stabilization of a spacecraft makes it possible to maintain the longitudinal axis of the satellite in a given direction for a very long time, which significantly increases the service life of the automatic station. On the other hand, continuous orientation of the satellite /42
towards the sun makes it possible to keep providing the station with electrical energy.

Four panels of solar batteries are used to generate electrical energy on board the stations, and a chemical current source is used as a buffer battery. As the telemetry information indicates, the electric supply system successfully performs its tasks, sufficiently providing the onboard systems of the satellite with electrical energy.

In order to maintain set thermal conditions in the airtight container, the "Prognoz" satellite series are provided with active and passive means of temperature control.

The control of onboard systems, the measurement of orbital parameters and motion parameters and obtaining the scientific and service information from onboard the stations are provided by the onboard radio telemetry complex together with a programming-timing device and by earth-bound equipment.

As a result of the great distances of the satellites from the earth's surface it is necessary to have a comparatively powerful transmitter on board. However the capacities of onboard current sources are not unlimited. Therefore it was decided to make a single transmission channel, and all systems, which have to use it were combined into one complex. Such combination made it possible to significantly lighten the radio equipment and to increase the reliability of information transmission. The extended location of the "Prognoz" automatic stations in zones of radio visibility from terrestrial transmitting and receiving stations makes it possible to use the most optimal communication section regimes, and of electrical energy consumption regimes.

During their flight the "Prognoz" automatic stations continually observe the activity of the sun and the condition of the surrounding environment. All the scientific information is transmitted to earth both in a mode of "direct transmission" of the results of observations in the real time scale, and is also preliminary recorded in a memory device and then transmitted in a "playback" mode.

The above-mentioned operating modes of the telemetry system make it possible to effectively use the results of the scientific observations made when the station is located at different distances from earth, at the proper time to "examine" in the altitude levels of the gaseous envelope of our planet, and also to gather information about the surrounding environment without any gaps.

At the present time the information obtained from the "Prognoz" automatic stations is undergoing detailed treatment and analysis. Preliminary results have already appeared in print. The data /43 which scientists have obtained has confirmed a number of already known facts about the evolution of the state of the upper atmosphere and the behavior of the mechanism of sun-earth interconnections and have led to the formulation of a number of new hypotheses.

In the general opinion of specialists, the given space experiment is a significant step forward. It is difficult to overestimate its scientific value. Therefore it is possible to state with assurance that such automatic stations in the future will undoubtedly keep constant watch in space, informing terrestrial services about the behavior of our star and the state of the upper layers of the atmosphere.

"SOYUZ" AND "APOLLO": THE JOINT FLIGHT PROJECT /44

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The agreement between the governments of the U.S.S.R. and the U.S.A. on cooperation in the investigation and use of outer space for peaceful purposes, signed on 24 May 1972 during the summit meeting in Moscow looks forward to conducting in 1975 a joint experimental flight of Soviet and American manned spacecraft and joining them with a mutual transfer of astronauts.

The tehnical aspects of performing such a flight were examined at the time of the preliminary discussions of representatives of the Academy of Sciences of the U.S.S.R. and the National Aeronautics and Space Administration of the U.S.A. (N.A.S.A.). At the manned flight center in Houston (U.S.A.) there was a meeting of Academy of Sciences U.S.S.R. and N.A.S.A. specialists, at which all aspects of the technical and organizational problems, relating to the development of joint faciliites for the rendezvous and docking of a Soviet spacecraft of the "Soyuz" and American spacecraft of the "Apollo" type, preparing for and conducting the flight, were discussed.

At the time of this meeting agreements were reached concerning the basic technical requirements for all systems, connected with the process of rendezvous and docking, the principles of the construction of common docking devices, the project development and flight plan.

The meeting proceeded in a businesslike fashion, which made it possible to discuss the many difficult problems of this complex space experiment and to reach agreements acceptable to all sides. Some problems were left to be discussed and agreed upon during the subsequent meetings of the working groups of Soviet and American specialists. However the agreement already achieved opens the possibility for further development of common rendezvous and docking facilities and preparation for the joint flight of spacecraft.

What are the problems of such a flight and what are its characteristics?

Providing manned spacecraft and stations with common /45 rendezvous and docking facilities pursues the humane purposes of increasing the safety of manned flights in space. Such facilities will provide for the possibility of docking in case of necessity of any spacecraft or orbital station with any other nearby spacecraft, if it is equipped with such devices, irrespective of whatever country it belongs to.

The main problem of the experimental flight of manned spacecraft of the "Soyuz" and "Apollo" types is to check the engineering solutions used and to test common rendezvous and docking facilities of the spacecraft and of their systems, providing for the possibility of the mutual transfer of astronauts from ship to ship. The creation of common facilities does not foresee the development of identical constructions. Each country will construct and prepare them independently, but on the basis of common principles and agreed upon requirements.

The technical difficulties arising here are connected both with the fact that up until now each country had developed rendezvous and docking systems in reference to its own programs, and also with the fact that for the future it is necessary to seek new structural principles, applicable for the docking of any two ships requiring it.

As a result of the joint work of Soviet and American specialists such principles have already been found and ways of overcoming the existing difficulties have been discovered, although there still remains much to be done in order to realize the necessary technical solutions.

Thus, the principle of the peripheral construction of a docking device of the so-called "androgenous" type has been developed. It is completely new, has not been realized in either country and will make it possible for each of the ships equipped with it to play both an active and a passive role. The transfer of astronauts from one ship to the other is performed through internal hatches without having the astronauts go into open space.

The problem is that at the present time in order to perform docking it is necessary to have two different types of docking devices, active and passive. The new construction differs from the existing ones by the fact that instead of a central probe on the active docking device and a receiving cone on the passive one each of them has directing "petals" placed along the periphery, tightening devices and locks, hatches located in the central part for the transfer of astronauts.

Another innovation is a special docking section, which is a component of the "Apollo" ship on the free end of which there is a docking mechanism compatible with the corresponding mechanism of the "Soyuz" ship. This section will serve as a lock for /46
atmospheric adaption during the transfer of astronauts. The necessity for this is caused by the fact that the atmosphere

of the "Soyuz" ship consists of ordinary air at a pressure of 760 millimeters of mercury and the atmosphere in "Apollo" of pure oxygen at a pressure of 260 millimeters of mercury. In the future, probably, the atmosphere of all spacecraft will be close to ordinary earth atmosphere, and then the necessity for a special air lock will no longer exist, but for the flight in preparation it is necessary.

Great attention has also been given to the compatibility of the rendezvous facilities of the ships, the radio equipment for communicating between ships and the ground control centers, including systems for direct transmission of voice (radio telephone) communication from one crew to the other during the rendezvous and docking process. It is agreed that the flight crews must learn the language of the other country in order to understand voice communication and to take the correct response actions. The familiarization of the astronauts with the spacecraft of the other country, joint training of crews, and also the joint testing of newly developed systems for rendezvous and docking are foreseen.

The sequence for carrying out the flight has been agreed upon. It is set for the second half of 1975. First a "Soyuz" type spacecraft will be launched from the Soviet space center. Approximately 7-1/2 hours later an "Apollo" type craft will be launched in the U.S.A. The possibility exists for launching the "Apollo" on the second or third day after the launch of the "Soyuz". The "Apollo" will perform an independent flight for about a day, and then the spacecraft will rendezvous and dock. In the docked state they form a manned space system which will be controlled and stabilized as a single unit. Its orbital flight will last appoximately two days. During this time there will be mutual transfers of astronauts and scientific experiments will be conducted. Television transmissions to Earth will be conducted. Then the astronauts will return to their own ships and perform undocking. Having completed their flight according to an independent program, they will land, "Soyuz" on the territory of the U.S.S.R., and "Apollo" in the Pacific Ocean.

In order to prepare for the intended flight both countries will have to do a great deal of work and overcome not a few difficulties.

The realization of this joint project is an important step forward in the development of international cooperation in the investigation and use of outer space for peaceful purposes. There is no doubt that cooperation in this region of technical progress will contribute an important contribution to the conquest of outer space in the interests of science, technology and all peoples.